

Filtration in Tail Gas Cleanup Units

Introduction

Refineries use various processes to reduce acid gases from process streams. In the amine sweetening process, acid gases are reduced from sour gas, and sent to the sulfur recovery unit, also called a Claus plant. Claus process technology, however, typically only provides about 96% sulfur recovery. In order to comply with emissions regulations, refineries often add a tail gas cleanup unit after the Claus plant to increase overall sulfur recovery to 99.9%. Filtration is required in the tail gas cleanup unit to protect process equipment and to maintain overall system efficiency. This Customer Application Brief (CAB) addresses the benefits of effective filtration.

The Process

The Claus plant recovers about 96% of total sulfur from the acid gas effluent created in the amine sweetening unit. The effluent from the Claus plant, commonly referred to as tail gas (a mixture of light ends and acid gases), is sent to the tail gas cleanup unit, where the acid gases – primarily hydrogen sulfide (H_2S), sulfur dioxide (SO_2), carbonyl sulfide (COS), and carbon disulfide (CS_2) – are heated and mixed with hydrogen in the presence of a cobalt-molybdenum catalyst. This reaction reduces all sulfur compounds in the tail gas to H_2S . The effluent from the reactor is then cooled in a quench column. The quench water serves to cool the stream to the appropriate temperature for amine contacting, and to absorb any residual SO_2 that breaks through the reactor. The cooled gas stream is then sent to the tail gas unit's amine contactor to reduce any residual H_2S . The treated tail gas is then sent to the thermal oxidizer, where any remaining sulfur compounds are converted to SO_2 . The tail gas/ SO_2 mixture is then flared to atmosphere. The rich amine is stripped of the H_2S and recirculated back to the contactor. The stripped H_2S is sent back to the Claus plant for reprocessing.

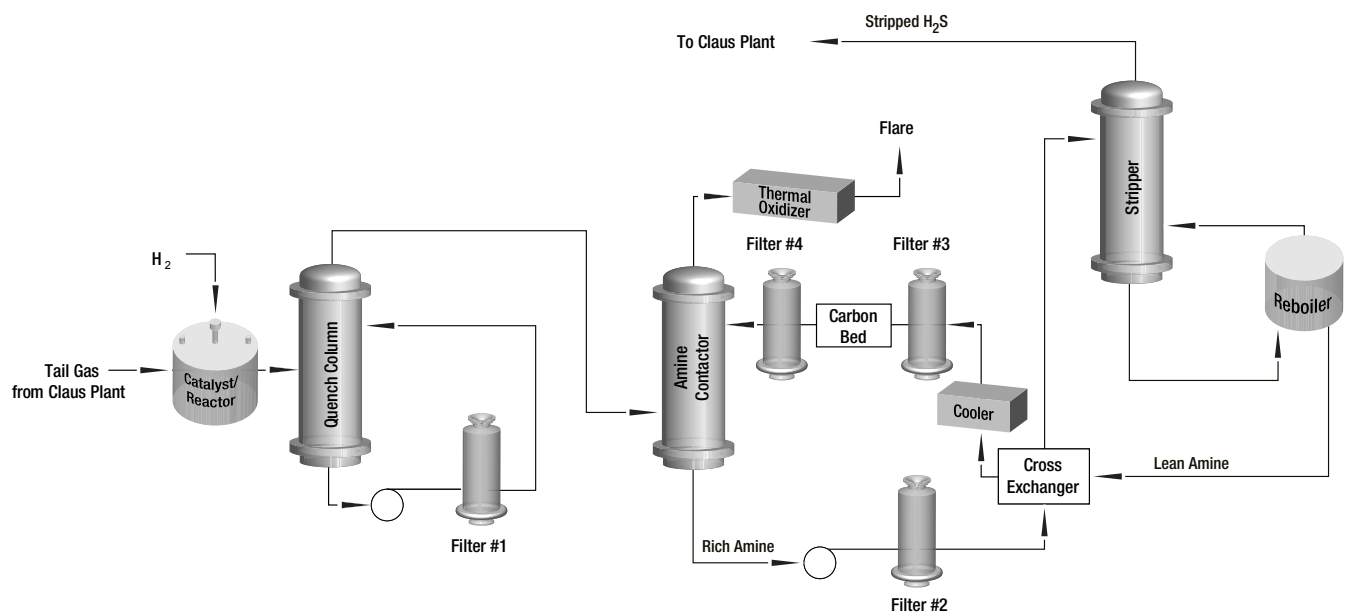


Figure 1 — Tail Gas Cleanup Unit

The Problem

Contamination in the tail gas cleanup unit can cause many problems, including:

Quench Column Section

Hydrogen Blistering – Although the reactor ideally reduces all sulfur compounds, including SO₂, to H₂S, some trace quantities of SO₂ may “break through.” The SO₂ reacts with H₂S in the quench water to form elemental sulfur. The sulfur must be filtered out to prevent sulfur deposits on the column and cooler internals. Unabated deposits of sulfur on process equipment internals can lead to hydrogen blistering, and can result in maintenance costs to clean equipment internal surfaces and lost revenues as the system is shut down for cleaning.

Amine Contacting Section

Contacting Plugging – Solids deposited on the trays of the contactor can plug the bubble caps on the trays, resulting in higher gas velocities through the trays. Higher velocities will increase the tendency of the amine to foam and not allow the gas to come in full contact with the amine at the subsequent trays. If contact is missed at enough trays, ineffective absorption can take place. Solids deposition on the trays will also increase differential pressure, resulting in amine carryover and eventually a maintenance shutdown to clean the trays.

Heat Exchanger / Reboiler Fouling

Solids deposited on the heat exchanger and reboiler tube surfaces cause poor heat transfer resulting in ineffective regeneration of the amine solution. As the reboiler tubes become fouled and ineffective regeneration occurs, operators typically increase heat to the reboiler to improve the regeneration process, which in turn results in higher energy usage. The tubes of the reboiler are not coated uniformly by the deposited solids and the additional heat to the reboiler causes “hot spots” to form. These hot spots, or points on the tubes where high temperatures exist, are sites where rapid degradation of the amine solution can occur. As amine degradation occurs, corrosion rates increase and the tendency of the amine to foam increases. As a result, amine carryover rates increase, maintenance costs are incurred to clean out the exchangers, and lost revenues occur as the system is shut down to complete the necessary repairs.

Carbon Bed Fouling

Contaminants introduced into the carbon bed increase differential pressure across the bed, block access to the active sites of the carbon, and increase the tendency for amine to “channel” through the bed. The result is reduced absorptive capacity, resulting in frequent carbon bed regeneration or, in the worst case, premature replacement of the carbon bed.

Foaming

Solids in the amine stabilize foaming that occurs by increasing the surface tension of the amine and making it more difficult for the individual foam “bubbles” to break. As previously described, if the foam is stable enough to prevent full contact at the next tray, ineffective absorption can occur. In addition, foaming results in high amine carryover rates and, therefore, high amine replacement costs.

The Solution

To reduce contamination problems, 3M Purification Inc. recommends four stages of filtration for optimal performance of tail gas cleanup units.

1. Filter 1 – Quench water filtration. Five-micron 3M™ DF series is recommended to filter the elemental sulfur in the quench water loop to adequately protect the quench section process equipment from hydrogen blistering.
2. Filter 2 – Recirculating amine system. Ten-micron 3M™ 740 series or Betapure™ PK series filters are recommended, depending on existing plant configuration. Locating the filter in the rich line upstream of the heat exchanger will reduce solid contamination including iron sulfide and corrosion products. This helps protect both the heat exchanger and the stripper.
3. Filters 3 & 4 – Upstream and downstream of the carbon bed. Ten-micron 3M 740 series or Betapure PK series filters are recommended, depending on existing plant configuration. The carbon bed reduces entrained hydrocarbons and surface active compounds, reducing the tendency of the amine solution in the contactor to foam. Locating the filter upstream of

the carbon filter reduces carbon bed fouling. Downstream filters will help protect the contactor by reducing carbon fines that would otherwise be deposited on the column's trays.

For Filter Position 1, 3M Purification recommends the 3M™ DF series filtration system. The unique design of the 3M DF series filter system can provide for up to 4 times more service life and 2 – 3 times more contaminant capture capacity than conventional bag filters translating into reduced change-out requirements.

Using baskets providing 3-dimensional support, 3M DF series elements can be retrofitted into most major manufacturers' bag housings. For new applications, 3M Purification has a complete line of 3M DF series filter housings available in a wide range of sizes including single element as well as multi-elements, and both carbon and stainless steel materials of construction.

Table 1 — 3M™ DF Series – Features & Benefits

| Features | Benefits |
|---|--|
| <ul style="list-style-type: none"> Unique filter design combining a graded-porosity media with 62% greater filter surface area | <ul style="list-style-type: none"> Longer service life – up to 4 times or more that of conventional filter bags Reduced filter usage – minimizes product loss, labor, disposal costs, and operator exposure Increased productivity – less down time for filter change-out |
| <ul style="list-style-type: none"> Hold-up volume reduced by 67% compared to conventional bag filters | <ul style="list-style-type: none"> Reduced product loss and related disposal costs Used element retains less fluid, making it lighter weight for easier reduction Helps reduce displacement balloons and associated spillage during change-out |
| <ul style="list-style-type: none"> 100% downstream support of the filter element | <ul style="list-style-type: none"> Helps reduce filter rupture, contaminant bypass, and unloading Allows operation to higher differential pressures before filter change-out |
| <ul style="list-style-type: none"> Superior flow characteristics | <ul style="list-style-type: none"> Maximizes utilization of filter surface area and maintains low operating pressure drop Reduces flow per unit area (flux) for improved effluent quality |

For Filter Positions 2, 3, and 4, 3M Purification recommends the following, depending on existing plant configuration.

- a) For full flow applications, the 3M™ 740 series filter is recommended. Absolute-rated 3M 740 series filters are proven performers in amine sweetening applications. Each cartridge is 6.5" diameter x 40" long, and is constructed from meltblown polypropylene micro-fiber media constructed in a radial pleat pattern. This unique design provides a large usable surface area to maximize loading capacity. User-friendly features such as a convenient handle and reduction of special tools or hardware facilitate easy operation and maintenance of the filter system.

Table 2 — 3M™ 740 Series – Features & Benefits

| Features | Benefits |
|--|--|
| <ul style="list-style-type: none"> Compound Radial Pleat design | <ul style="list-style-type: none"> Provides more surface area in a given volume than many other types of conventional filters High loading capacity for long life and lower cost filtration Fewer cartridges to purchase and hold in inventory |
| <ul style="list-style-type: none"> Absolute rating | <ul style="list-style-type: none"> Reproducible effluent quality throughout the filter's life |
| <ul style="list-style-type: none"> Double O-ring seals | <ul style="list-style-type: none"> Reduces risk of bypass |
| <ul style="list-style-type: none"> Easy to Use | <ul style="list-style-type: none"> No tools or hardware required for filter change-out – minimizes downtime No springs or caps to lose – minimizes downtime and reduces risk of bypass Convenient handle for easy cartridge insertion and reduction |

- b) For applications where smaller diameter cartridges are preferred, 3M Purification recommends absolute-rated Betapure™ PK series depth filter cartridges. Betapure PK series filter cartridges are manufactured using a process that achieves a rigid, true graded pore structure with a clean and smooth inside diameter, eliminating the need for a center core. An optimized groove pattern increases the surface area by over 65% when compared to smooth cylindrical cartridges. These features allow Betapure PK series to provide significantly greater service life than competitive filter cartridges of comparable efficiency.

Table 3 — Betapure™ PK Series – Features & Benefits

| Features | Benefits |
|---|--|
| <ul style="list-style-type: none"> Absolute-rated cartridge filters from 10 – 60 microns | <ul style="list-style-type: none"> Reproducible effluent quality throughout the filter's life |
| <ul style="list-style-type: none"> Grooved surface with true graded-porosity structure | <ul style="list-style-type: none"> Dramatic cost savings with optimized yields |
| <ul style="list-style-type: none"> "336" cartridge elastomer sealing system | <ul style="list-style-type: none"> Fast filter change-out and consistent product quality |
| <ul style="list-style-type: none"> No metal or plastic cores | <ul style="list-style-type: none"> Reduced disposal costs |
| <ul style="list-style-type: none"> Available in 2 5/8" OD, 3" OD, and 4 1/2" OD and lengths to 72" | <ul style="list-style-type: none"> Retrofit existing housings and current applications |

Conclusion

Efficient reduction of contaminants is critical to proper operation of the tail gas cleanup unit, including protecting process equipment and reducing maintenance costs. The use of 3M™ DF series, 3M™ 740 series, and Betapure™ PK series filters will improve unit efficiency while helping to protect process equipment and reducing overall maintenance costs.

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